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Examining the Effectiveness of Community-Based Renewable Energy Solutions in Addressing Clean Energy Gaps: A Case Study of Chawama Constituency in Lusaka

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Abstract
Despite Zambia's growing commitment to renewable energy through the National Energy Policy (2019), peri-urban communities such as Chawama Constituency in Lusaka continue to face persistent energy poverty. Only about 52% of households in informal settlements have access to reliable electricity, constrained by frequent outages, high connection costs, and weak grid infrastructure. Community-Based Renewable Energy (CBRE) solutions, particularly solar home systems, kiosks, and institutional installations, have emerged as alternatives, yet their effectiveness and sustainability in low-income urban contexts remain insufficiently documented. This study therefore examined the effectiveness of CBRE solutions in addressing clean energy gaps in Chawama Constituency. A descriptive case study design was employed, integrating quantitative surveys with qualitative key informant interviews (KIIs). Structured questionnaires were administered to 80 households and 5 solar kiosk operators, while 13 key informant interviews were conducted with school administrators, health workers, and local leaders, producing 98 valid responses. Quantitative data were analyzed using SPSS version 27 to generate descriptive statistics and cross-tabulations, while qualitative data were thematically analyzed. This methodological triangulation enhanced reliability and validity by combining statistical evidence with lived experiences. Findings revealed that solar home systems (78.8%), solar lanterns (71.8%), and kiosks (52.9%) were the predominant CBRE technologies. Approximately 78.8% of respondents accessed at least five hours of electricity daily, and 77.7% reported lower energy costs after adoption. The systems enhanced livelihoods through small enterprises such as phone charging and retail operations, improved educational outcomes by extending study hours, and strengthened health services through reliable lighting. Sustainability was moderately strong, with 62.4% of respondents confident that their systems would remain functional for at least five more years. However, challenges included high maintenance costs, limited spare parts, and weak institutional coordination. The findings confirm that CBRE solutions have moderately improved energy access, affordability, and socio-economic welfare in Chawama, embodying the principles of distributional, procedural, and recognition justice under the Energy Justice Framework. Sustainable impact depends on strengthening community governance, enhancing technical capacity, and institutionalizing support mechanisms for maintenance and reinvestment. The study concludes that participatory, inclusive, and locally governed renewable energy systems provide a viable model for achieving equitable and enduring clean energy transitions in Zambia's peri-urban settlements.

Keywords: Community-Based Renewable Energy, Energy Access, Solar Home Systems, Sustainability, Energy Justice, Chawama, Zambia

1. Introduction

1.1 Background of the Study

Community-based renewable energy solutions refer to decentralized, locally managed initiatives that harness sustainable energy sources such as solar, wind, biogas, and mini-hydro to provide affordable and clean energy to underserved populations. These solutions are rooted in community participation, enabling local ownership, management, and distribution of energy systems to address energy poverty, promote equity, and foster sustainability (IRENA, 2022) [16]. With rising global concerns about climate change, energy insecurity, and environmental degradation, the deployment of renewable energy technologies has

gained traction as a crucial pathway toward achieving clean and inclusive energy access.

Globally, nearly 675 million people were without access to electricity as of 2021, with the majority residing in developing nations (IEA, 2023) [15]. While significant strides have been made in improving electrification rates, access remains unequal, especially in low-income urban, peri-urban, and rural areas. The United Nations Sustainable Development Goal 7 (SDG 7) emphasizes ensuring affordable, reliable, sustainable, and modern energy for all by 2030. In support of this, international frameworks such as the Paris Agreement (2015) and initiatives like Sustainable Energy for All (SEforALL) have advocated for expanded use of decentralized renewable energy systems, particularly through community-led models that promote inclusivity, empowerment, and resilience.

In the Sub-Saharan African context, energy poverty remains a pressing issue, with over 570 million people lacking access to electricity (World Bank, 2022) [43]. Despite being endowed with abundant solar and wind potential, the region continues to face infrastructural, financial, and policy-related barriers to universal energy access. National grids are often overstretched, and centralized energy systems fail to serve the growing urban poor in informal settlements. Community-based renewable energy interventions are increasingly being explored as an alternative approach to bridge these energy gaps. Countries such as Kenya and Rwanda have piloted solar microgrids and biogas systems managed by local cooperatives with encouraging results (Maringa & Tumwebaze, 2020) [21].

Zambia, like many Sub-Saharan countries, faces critical energy access challenges. While the national electrification rate stood at 44.6% in 2021, rural areas recorded only 11.9% access, and peri-urban informal settlements like Chawama still experience erratic supply and unaffordability (Zambia Energy Regulation Board, 2022) [45]. The Zambian government, through policies such as the National Energy Policy (2019), has committed to diversifying its energy mix and expanding access through off-grid and renewable energy solutions. Additionally, Zambia is a signatory to regional and international agreements promoting clean energy transition, including the Southern African Development Community (SADC) Renewable Energy Strategy and Action Plan (2016-2030).

In Chawama Constituency, a densely populated low-income peri-urban area in Lusaka, unreliable access to electricity has constrained economic productivity, household welfare, and public services such as health and education. Residents face frequent power outages, high electricity costs, and limited infrastructure to support small-scale energy alternatives. Nevertheless, local efforts have emerged to implement community-based renewable solutions, especially small solar home systems, energy kiosks, and solar-powered street lighting, often supported by NGOs, local entrepreneurs, or donor-funded projects. However, questions remain regarding the scale, effectiveness, and sustainability of these initiatives in addressing Chawama's persistent energy challenges.

From a development perspective, community-based energy systems are argued to foster greater resilience, ownership, and gender inclusiveness (UNDP, 2020) [40]. However, critiques have emerged around their scalability, technical reliability, and maintenance costs in low-resource settings (Ahlborg & Hammar, 2016) [1]. Understanding how these models perform in contexts such as Chawama, where formal energy access remains limited, is vital for informing policy, investment, and community empowerment.

This study seeks to explore how community-driven renewable energy interventions are being utilized in Chawama Constituency, the extent to which they are effective in reducing clean energy gaps, and whether they can provide a sustainable model for urban electrification in Zambia and beyond.

1.2 Statement of the Problem

Despite global and national efforts to expand clean energy, peri-urban communities in Zambia, such as Chawama Constituency, still face persistent energy poverty. The Zambia Energy Regulation Board (2022) [45] reports that only 52% of households in informal settlements like Chawama have reliable access to electricity, and affordability remains a challenge. Frequent blackouts, high connection costs, and poor grid infrastructure further restrict both household and economic use (ZESCO, 2021) [46]. Community-based renewable energy initiatives, including solar mini-grids and home systems, have emerged as alternatives, yet their actual effectiveness in low-income peri-urban contexts is largely undocumented. While the National Energy Policy (2019) advocates decentralized solutions, weak monitoring and inadequate financing hinder adoption. This research therefore seeks to assess whether such interventions meaningfully address local energy needs or remain short-term measures with limited long-term impact.

1.3 Objective

1.3.1 General Objective

To examine the effectiveness of community-based renewable energy solutions in addressing clean energy gaps in Chawama Constituency, Lusaka.

1.3.2 Specific Objectives

1. To analyze the types of community-based renewable energy solutions implemented to address clean energy gaps in Chawama Constituency.
2. To assess the effectiveness of community-based renewable energy solutions in addressing clean energy gaps in Chawama Constituency.
3. To ascertain the sustainability of community-based renewable energy solutions in providing long-term clean energy access in Chawama Constituency.

1.4 Research Questions

1. What types of community-based renewable energy solutions have been implemented to address clean energy gaps in Chawama Constituency?
2. How effective are these community-based renewable energy solutions in addressing clean energy gaps in Chawama Constituency?
3. To what extent are the community-based renewable energy solutions in Chawama Constituency sustainable in providing long-term clean energy access?

1.5 Theoretical Framework

This study is guided by the Energy Justice Framework, which emphasizes fairness and equity in the distribution, governance, and recognition of energy systems (Sovacool *et al*., 2016 [36]; Jenkins *et al*., 2017). It comprises three key dimensions: distributional justice, addressing equitable

access and affordability of energy; procedural justice, ensuring transparency and community participation in decision-making; and recognition justice, acknowledging diverse social and cultural contexts. These dimensions are particularly relevant in peri-urban areas like Chawama, where poverty and infrastructure deficits intersect with energy inequality. The framework aligns with the study's objectives by assessing the types, effectiveness, and sustainability of community-based renewable energy solutions, ensuring that analysis goes beyond technical outcomes to include inclusivity, fairness, and long-term social impact.

2. Literature Review

2.1 Types of Community-Based Renewable Energy Solutions

Global literature evaluates the diversification of community-based renewable energy (CBRE) solutions, showing consistent uptake of solar, wind, bioenergy, and hybrid systems across varied policy environments. Walker and Devine-Wright (2016) [41] conducted qualitative case studies in England and Wales and found that co-owned wind farms and community investment schemes perform best where social capital and local identity are strong. Their interviews and site visits reveal that CBRE types function as institutional arrangements rather than technical installations, concluding that ownership, participation, and identity alignment determine viability. Bauwens *et al*. (2016) [5] analysed more than 1,000 German energy cooperatives using mixed methods and identified solar PV cooperatives, citizen wind projects, and biogas plants as dominant forms. They argue that supportive feed-in tariffs shaped these typologies and conclude that cooperative ownership models enable scale.

Hicks and Ison (2018) [11], studying the Hepburn Wind cooperative in Australia through interviews and case documentation, report that community wind farms and solar bulk-buy schemes prevail. They comment that democratic governance and local financing anchor adoption. Del Río and Mir-Artigues (2019) [10], comparing Spain, Germany, and Denmark through document analysis and stakeholder interviews, observe that Spanish CBREs are led by solar cooperatives and shared rooftop systems and argue that despite policy instability, strong civic engagement sustains diversification. Together, global studies converge on the dominance of solar and wind cooperatives and contend that CBRE typologies are shaped by governance, policy incentives, and community participation.

Regional evidence from Sub-Saharan Africa illustrates expanding CBRE types shaped by infrastructure gaps, affordability constraints, and informal governance. Taneja and Acey (2017) [37] used surveys (n=350) and interviews in Kenya to assess solar micro-grids managed by community committees, finding that 10–50 household clusters benefit from prepaid metering and reduced diesel reliance. Ulsrud *et al*. (2018) [39], through ethnography in Uganda, identified solar home systems and battery-rental models as prevalent CBRE types and argue that trust networks and informal credit underpin adoption.

Martinot *et al*. (2019) [22] evaluated Rwanda's solar kiosks and mini-hydro schemes using longitudinal program data and conclude that public-private-community partnerships diversify CBRE options but remain subsidy-dependent. Ilori *et al*. (2020) [13], applying participatory action research in Lagos, found biogas units and solar streetlights to be leading CBRE forms and contend that inclusive planning reduces vandalism and strengthens legitimacy. Collectively, regional literature emphasises solar micro-grids, SHSs, kiosks, and institutional biogas as the most widespread types and evaluates their success as dependent on local norms, financing systems, and community governance.

Local Zambian studies demonstrate high CBRE diversification, with evidence weighted toward peri-urban Lusaka. Mwanza and Phiri (2021) [27] used interviews and observations in Lusaka, including Chawama, and identified solar kiosks operated by youth cooperatives as key CBRE types enabling charging and lighting services; they contend that viability depends on micro-finance and entrepreneurial capacity.

Chilala and Moonga (2022) [8], using mixed methods, describe subsidized SHSs distributed through cooperatives such as the Chawama Green Energy Youth Group and criticize weak supply chains and limited user training. Tembo and Banda (2019) [38], analysing surveys (n=200), identify widespread use of user-owned SHSs and communal charging stations and argue that informal micro-enterprises supply critical CBRE access.

Musonda *et al*. (2023) [26], studying 13 institutions in Lusaka, document solar systems in clinics and schools managed by community committees and conclude that institutional CBREs improve service delivery but require technical support. Together, Zambian literature affirms CBRE types ranging from SHSs and kiosks to institutional solar and charging hubs, emphasising community co-design, financing mechanisms, and governance as determinants of durability.

2.2 Effectiveness of Community-Based Renewable Energy Solutions

Global evidence occupies a small but foundational share of the literature and evaluates CBRE effectiveness through access gains, reliability, socio-economic impact, and governance quality. Sovacool *et al*. (2018) conducted a meta-analysis of 400 CBRE projects across 45 countries using content analysis of performance assessments. They report that 68 percent of projects met energy-access targets and argue that participatory governance and post-installation support drove effectiveness. They conclude that outcomes improve when distributional and procedural justice are embedded.

Hicks and Ison (2018) [11] examined Hepburn Wind in Australia through interviews and performance data, finding that the cooperative supplied power to over 2,000 households and reinvested revenue locally. They assess the project as effective due to uninterrupted generation and strong community legitimacy.

Creamer *et al*. (2019) used mixed methods to assess 12 UK CBRE projects and found that although most achieved energy delivery, only 60 percent were financially stable. They argue that effectiveness depends on context and policy alignment. Bauwens and Devine-Wright (2020) [4] evaluated 1,200 German energy cooperatives using survey and grid data and found that solar and wind cooperatives supplied electricity to more than 4 million households. They contend that institutional stability and community ownership sustain long-term reliability.

Regional Sub-Saharan African studies provide deeper empirical grounding. Odarno *et al*. (2020) [30] assessed 12

solar mini-grids in Tanzania and Ghana using household surveys (n=800) and operator interviews. They report reliable power for over 70 percent of target users and argue that inclusive governance increases satisfaction, while weak tariff design constrains utilization.

Kirubi (2016) [19] evaluated micro-grids in Kenya through longitudinal audits and interviews with 120 households and enterprises. They found extended working hours, improved school performance, and reliability constraints linked to inadequate storage. Sagna *et al*. (2021) [33] assessed solar agro-processing CBREs in Senegal through surveys and focus groups. They found post-harvest losses reduced by 45 percent and incomes rising 62 percent, arguing that productive-use alignment drives effectiveness.

Mawejje and Sebudde (2019) [23] evaluated Uganda's solar-kit dissemination using randomized surveys and expenditure diaries, finding a 70 percent fall in kerosene use and 35 percent decline in energy-related health problems. They contend that technical literacy gaps undermine long-term system survival.

Local Zambian evidence is the most extensive and anchors CBRE effectiveness within peri-urban Lusaka. Phiri and Kalinda (2020) [32] assessed solar kiosks in Chawama and Kanyama using 60 user surveys and operator interviews. They found that kiosks met over 80 percent of basic lighting needs and argue that affordability and local management drive consistent performance.

Mwale and Kanyanta (2022) evaluated solar systems in ten Lusaka schools using pre/post analysis and interviews, finding extended study hours, improved safety, and a 17 percent enrolment increase. They contend that training and community ownership mediate system longevity. Simutenda *et al*. (2021) [34] reviewed solar-powered clinics through audits and interviews with 18 health workers and report improved vaccine refrigeration, 38 percent fewer emergency referrals, and higher patient satisfaction. They argue that effectiveness is strongest when systems support critical health functions.

Lukwesa and Hamanungu (2019) [20] surveyed 150 households using SHSs in Chawama and George Compound and found that 72 percent met daily needs and kerosene costs fell by 85 percent. They criticise weak supply chains and assert that maintenance access determines long-term impact.

Chibwe and Mbewe (2021) used participatory methods to assess women-led solar initiatives in Chawama and found reduced firewood dependence and improved safety. Zulu and Ng'ombe (2020) [47] examined solar agro-processing units and report 40 percent income increases and 60 percent loss reductions. Mumba and Chileshe (2023) [25] compared delivery models and found PAYG systems achieved 78 percent satisfaction due to flexible payments. Chama and Moonga (2021) [6] assessed a community biogas project and found a 25 percent waste-volume reduction and reliable communal cooking.

Nakazwe *et al*. (2022) [28] audited solar systems in schools and clinics and found a 90 percent cut in generator fuel use but delays in repairs. Mundia and Banda (2018) found WDC-supervised systems had a 15 percent failure rate versus 35 percent in NGO-led installations and argue that decentralised governance increases effectiveness.

2.3 Sustainability of Community-Based Renewable Energy Solutions

Global evidence establishes sustainability as a function of governance, financial durability, and technical resilience. Sovacool *et al*. (2021) conducted a global meta-review of 400 CBRE projects across Asia, Africa, and Europe using content analysis and case comparisons. They found that projects with structured governance and reinvestment mechanisms achieved over 60 percent higher long-term survival. They argue that donor-dependent projects without maintenance plans collapse early.

Hicks and Ison (2018) [11] evaluated the Hepburn Wind cooperative in Australia through interviews and financial audits. They report uninterrupted operation for over ten years, dividend distribution, and locally reinvested revenue, and contend that democratic governance and financial autonomy anchor sustainability. Wirth (2014) [42] examined German energy cooperatives using ten-year financial records from 100 solar and wind cooperatives. He observed that cooperatives with diversified revenue streams remained viable after FIT reductions. He argues that CBREs require buffers against policy volatility.

Hoffman and High-Pippert (2015) [12] studied shared solar cooperatives in Minnesota through ethnographic analysis and found six-year system continuity driven by leadership rotation and member training. They contend that accountability and civic engagement reinforce sustainability.

Regional Sub-Saharan African studies emphasise economic integration, institutional coordination, and technical literacy. Aklin *et al*. (2018) assessed 600 Tanzanian households over five years and found 68 percent of solar home systems functional after four years due to PAYG financing, while limited spare-part access undermined continuity. They argue that sustainability requires matching technology with financing and supply chains.

Ulsrud *et al*. (2018) [39] evaluated solar mini-grids in Uganda's Tororo District using participatory mapping and governance audits. They found operational systems but weak tariff compliance, with only 45 percent of users paying regularly. They conclude that sustainability depends on professionalised community management. Kemausuor *et al*. (2020) examined six Ghanaian mini-grids through mixed methods and found higher sustainability where agricultural cooperatives co-managed systems, enabling tariff collection and reinvestment. They argue that CBREs endure when embedded in existing institutions.

Ilskog and Kjellström (2019) [14] compared Kenyan micro-hydro and solar schemes using a sustainability index and found micro-hydro superior due to integration with productive uses. They assert that income-linked CBREs fund their own maintenance.

Local Zambian evidence shows sustainability is strongest where community ownership, training, and economic use converge. Phiri and Lungu (2020) assessed solar kiosks in Chawama and Kanyama via interviews and found cooperative-run kiosks more durable due to fee collection and reinvestment, while informal kiosks faced theft and breakdowns. Mwansa and Mphande (2019) evaluated five peri-urban school systems using maintenance records and focus groups and found sustainability higher where energy subcommittees under PTAs managed upkeep.

Chileshe and Zulu (2021) assessed four solar-powered health centres through audits and interviews and found sustainability limited by lack of training and absence of recurrent budgets, with one system failing after 18 months. Ngoma and Mweemba (2022) [29] examined women-led solar cooperatives through participatory research and found ROSCA-based finance enabled upgrades after 18 months. They argue that social capital stabilizes CBRE operations.

2.4 Establishment of Research Gap

While the literature provides valuable insights into the types, effectiveness, and sustainability of community-based renewable energy (CBRE) solutions globally, regionally, and locally, several critical gaps persist. In the first thematic area, although various CBRE types such as solar kiosks, biogas systems, and solar home systems are well documented, there is a lack of empirical studies that map how these technologies evolve or scale over time in dynamic urban settings like Chawama. Furthermore, typologies are often explored without sufficient analysis of how local governance, informal market actors, or urban land tenure systems influence their adaptation. Under the second thematic area, the assessment of CBRE effectiveness tends to focus on short-term outputs such as electricity access or user satisfaction, but few studies link effectiveness to broader development outcomes such as income growth, education performance, or healthcare improvement in a measurable, long-term way. There is also minimal comparative evaluation between delivery models, which limits policy insights on which models perform better in informal settlements. And lastly, for theme three, sustainability analyses rarely consider the impact of policy fragmentation or climate-related stressors on CBRE durability, and few studies integrate feedback loops into national energy strategies. Collectively, these gaps signal the need for context-specific, policy-aligned, and impact-driven research on CBRE solutions in areas like Chawama Constituency. This study addresses these gaps by examining CBRE solutions in Chawama through the Energy Justice Framework, thereby linking local experiences with policy and sustainability debates.

3. Research Methodology

3.1 Research Design

The study adopted a descriptive case study research design to examine community-based renewable energy initiatives in Chawama Constituency, allowing investigation of complex real-life conditions linked to energy access challenges (Yin, 2018) [44]. The design integrated quantitative and qualitative approaches to capture measurable indicators and contextual experiences. Structured questionnaires gathered data on cost, reliability, usage, satisfaction, and benefits from households and kiosk operators. Key informant interviews provided additional insights from schools, clinics, and local authorities. This combination strengthened triangulation and enabled deeper exploration of the effectiveness and sustainability of community-based renewable energy initiatives (Aklin *et al*., 2018).

3.2 Target Population

The target population comprised household beneficiaries, renewable energy service providers, and institutional actors in Chawama Constituency. Household heads were included as primary users of solar systems addressing energy gaps, while solar kiosk operators represented service delivery and maintenance roles. Institutional actors such as school administrators, health workers, and local governance officials were added for policy and community insights. These stakeholder groups captured user experiences, operational realities, and governance perspectives, reflecting recommended diversity in community energy research (Ulsrud *et al*., 2018) [39].

3.3 Sampling Design and Sample Size

A purposive sampling approach was used to select participants with direct experience in community-based renewable energy systems in Chawama, ensuring contextual relevance and informed responses (Palinkas *et al*., 2015). The study involved eighty household heads, five solar kiosk operators, and fifteen key informants, giving a total of one hundred respondents. The household sample was determined using Yamane's (1967) formula for a population of four hundred: $n = 400 / (1 + 400(0.0866^2)) = 100$. Key informants included school administrators, health personnel, and local governance actors, strengthening data diversity and credibility.

3.4 Data Collection Methods

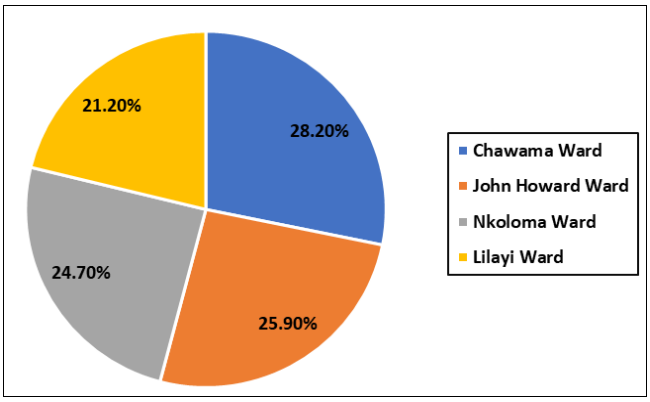
Data collection used structured questionnaires and key informant interviews to obtain quantitative and qualitative information. Questionnaires captured data on access, affordability, reliability, satisfaction, system breakdowns, maintenance, and perceived benefits among households and kiosk operators. Interviews with school administrators, health workers, and local officials provided insights on policy integration, community acceptance, and sustainability issues. This combination enhanced validity through cross-verification of household and institutional perspectives.

3.5 Data Analysis

The study used a mixed-methods analytical approach to interpret quantitative and qualitative data. Questionnaire responses were coded and analysed in SPSS version 27 and Microsoft Excel 2021 to generate descriptive statistics such as frequencies, means, and percentages showing variations in affordability, reliability, usage, and satisfaction. Cross-tabulations examined links between socio-economic factors and renewable energy adoption. Qualitative interview data were transcribed and analysed through thematic content analysis to identify patterns in governance, sustainability, and system effectiveness, ensuring comprehensive interpretation of community-based renewable energy performance.

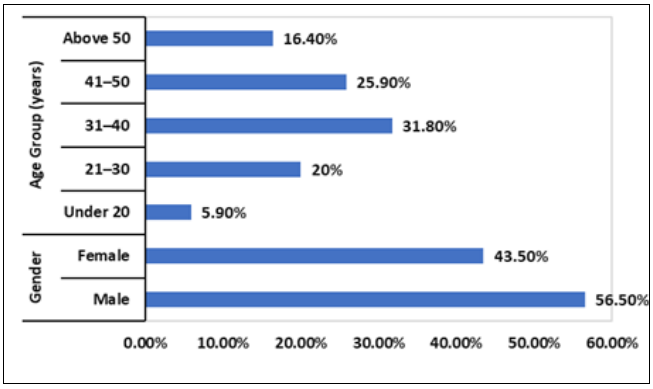
4. Findings and Results

4.1 Background Characteristics of Respondents



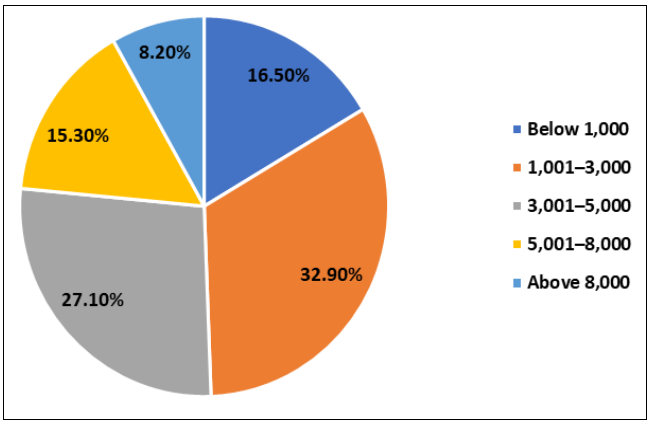
Source: Primary Data, 2025

Fig 1: Distribution of Respondents by Ward



Source: Primary Data, 2025

Fig 2: Gender and Age Groups



Source: Primary Data, 2025

Fig 3: Monthly Household Income

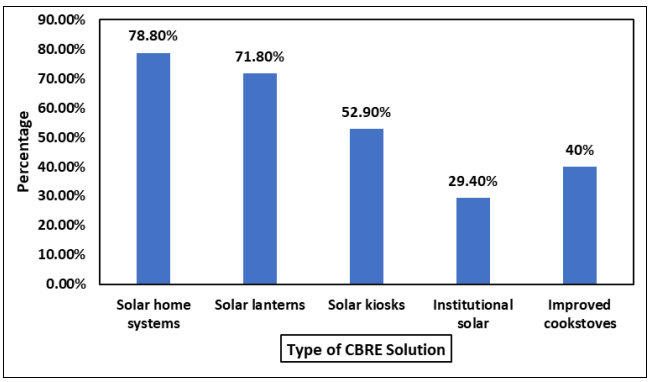
This section outlines the demographic profile of the 85 respondents, including 80 household beneficiaries and 5 solar kiosk operators, all of whom completed the questionnaire, yielding a 100% response rate. Respondents were drawn from Chawama Constituency's four wards with Chawama Ward contributing 24 respondents (28.2%), John Howard 22 (25.9%), Nkoloma 21 (24.7%), and Lilayi 18 (21.2%). This even spread enhances the generalizability of the findings across high-density and peri-urban areas. Gender distribution indicated a predominance of males (48; 56.5%) over females (37; 43.5%), reflecting patterns where men often make income-related energy decisions, while women primarily manage domestic energy usage.

Age analysis revealed that respondents were largely economically active, 31.8% were aged 31-40 years, 25.9% were 41-50 years, 20.0% were 21-30 years, 16.4% were above 50 years, and only 5.9% were under 20 years. Educational attainment was generally high, with 42.4% having completed secondary education and 40.0% tertiary qualifications, suggesting that participants possess the literacy required to understand and engage with renewable energy technologies.

Occupationally, informal business or trading was most common (40.0%), followed by formal employment (21.2%), farming (10.6%), students (8.2%), and unemployed respondents (20.0%), highlighting CBRE's relevance to income-generating and household activities. Household sizes were primarily medium, with 4-6 members in 45.9% of households and 7-9 members in 34.1%, indicating higher daily energy demands.

Monthly household incomes were mostly in low- to middle-income ranges, with 32.9% earning ZMW 1,001-3,000 and 27.1% earning ZMW 3,001-5,000, while only 8.2% reported incomes above ZMW 8,000. This demonstrates CBRE solutions' affordability and accessibility, aligning with inclusive energy objectives in peri-urban Zambia.

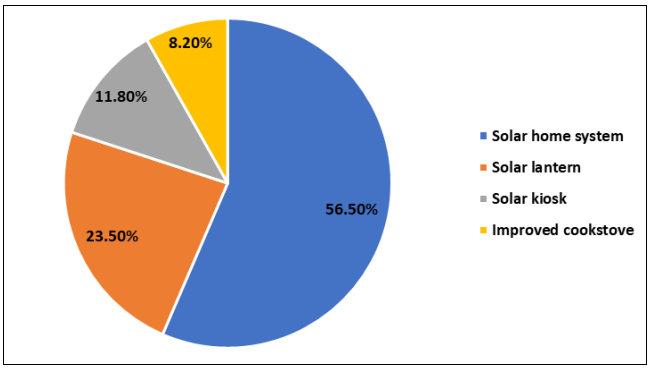
4.2 Types of Community-Based Renewable Energy Solutions



Source: Primary Data
Note: Multiple responses were allowed

Fig 4: Types of Renewable Energy Solutions Available in Chawama

Most respondents reported access to solar-based technologies, with 78.8% citing solar home systems and 71.8% solar lanterns as the most common options. Solar kiosks were mentioned by 52.9% of the 85 respondents, while institutional solar installations were noted by 29.4% and improved cookstoves by 40.0%. These findings confirm that Chawama's renewable energy landscape is heavily solar-driven. A local school administrator explained, "Solar units have become the main backup when ZESCO power is out, especially for lighting and phone charging." This highlights Solar's centrality in community energy resilience.



Source: Primary Data

Fig 5: Most Frequently Used Renewable Energy Solution

Solar home systems (56.5%) are the most frequently used, followed by lanterns (23.5%) and kiosks (11.8%). Improved cookstoves (8.2%) remain niche. Income cross-analysis showed low-income households favor lanterns, while higher-income groups own home systems. A school administrator noted, "Solar kits keep lights on during outages; homes with them can study longer." This confirms that household-level solar use drives Chawama's clean-energy adoption.

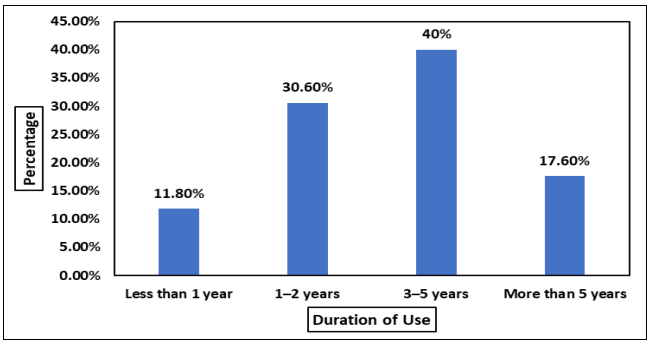
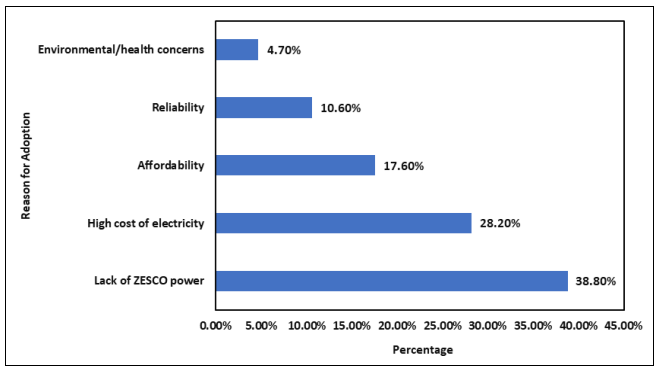


Fig 6: Duration of Use of CBRE Solutions

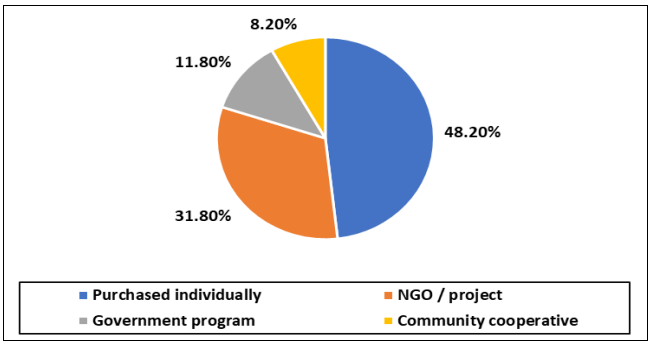
Most respondents (40.0%) had used CBRE for 3-5 years, 30.6% for 1-2 years, and 17.6% for over five years, indicating established adoption. A health worker stated, "Our solar was installed five years ago and still powers maternity lights." Sustained use reflects confidence in reliability and gradual normalization of renewable energy within households and institutions.



Source: Primary Data

Fig 7: Main Reasons for Adopting CBRE Solutions

Energy insecurity motivated most adoptions: 38.8% cited lack of ZESCO power and 28.2% high electricity costs. Affordability (17.6%) and reliability (10.6%) followed. A local official observed, "Power cuts forced people to go solar, it's survival, not luxury." These findings reveal cost and reliability as the primary adoption drivers, with limited uptake for environmental reasons.



Source: Primary Data

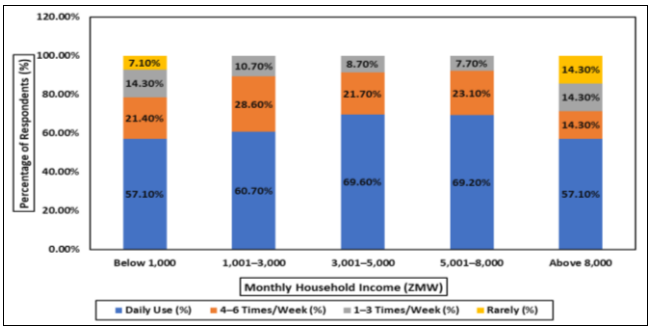
Fig 8: Channels of Access to CBRE Solutions

Almost half (48.2%) purchased systems individually, while 31.8% received them through NGO projects. Only 11.8% accessed government schemes. A KII respondent from local government remarked, "NGOs filled the gap where public programs were absent." This suggests that non-state actors remain central to renewable-energy diffusion in Chawama.

Table 1: Cross-Tabulation: Gender and Management of CBRE Systems

Gender of Respondent	Male-Managed	Female-Managed	Shared	Youth	Total
Male respondents	64.6%	10.4%	20.8%	4.2%	100%
Female respondents	29.7%	48.6%	18.9%	2.8%	100%
Overall	**49.4%**	**27.1%**	**20.0%**	**3.5%**	**100%**

The cross-tab shows that male respondents primarily manage household CBRE systems (64.6%), whereas female respondents exercise greater control when they are household heads (48.6%). Shared management occurred in 20.0% of households, while youth-managed systems were minimal (3.5%). A key informant explained, "Most men handle installations, but women ensure daily operation." These results suggest that men dominate technical and financial decisions, while women play vital roles in operational sustainability, highlighting evolving intra-household energy governance in Chawama.



Source: Primary Data

Fig 9: Cross-Tabulation: Income Level and Frequency of CBRE Use

The results show that daily use of community-based renewable energy (CBRE) was highest among households earning between ZMW 3,001 and 8,000, with 69.6% and 69.2% respectively, reflecting consistent reliance among

middle-income users. Households earning ZMW 1,001–3,000 also recorded a high daily usage rate of 60.7%, while both the lowest-income (below ZMW 1,000) and highest-income (above ZMW 8,000) groups had the lowest at 57.1%. Moderate use (4-6 times per week) ranged between 21.4% and 28.6%, mostly among lower- and middle-income earners, suggesting access influenced by affordability. Rare use was mainly among higher-income households (14.3%), likely due to alternative energy options. Overall, CBRE use cuts across income levels, driven more by reliability and affordability than by income, as also noted by one kiosk operator who explained that even low-income households depend on solar daily because it is "cheaper than candles or generators".

Table 2: Services Supported by CBRE Solutions

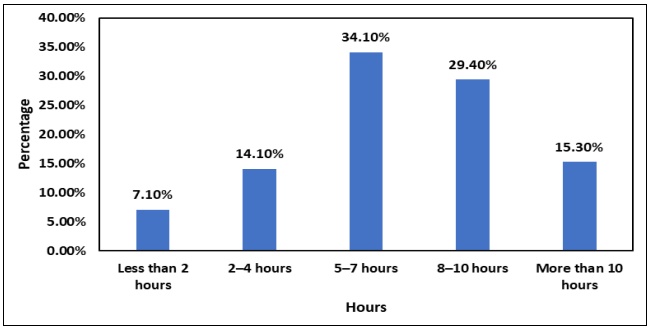
Service Type	Frequency	Percentage
Lighting	82	96.5%
Phone charging	77	90.6%
Radio / TV	60	70.6%
Small business	38	44.7%
Schoolwork	30	35.3%
Health (refrigeration, clinics)	19	22.4%
Cooking	9	10.6%
Water pumping	4	4.7%

Note: Multiple responses were allowed

Lighting (96.5%) and phone charging (90.6%) dominated CBRE uses, followed by radio/TV (70.6%) and small businesses (44.7%). Education and health benefits were cited by 35.3% and 22.4% respectively. A clinic officer explained, "Solar lights keep vaccines safe and night deliveries possible." This confirms CBRE's practical contribution to welfare and micro-enterprise. Less common uses included cooking (10.6%) and water pumping (4.7%), consistent with technological and affordability constraints.

A clinic officer explained, "Solar lights keep vaccines safe and night deliveries possible." This confirms CBRE's practical contribution to welfare and micro-enterprise. While Kiosk operators noted that energy-intensive uses like cooking remain uneconomical with current solar capacities, though prospects exist for future system scaling.

4.3 Effectiveness of Community-Based Renewable Energy Solution

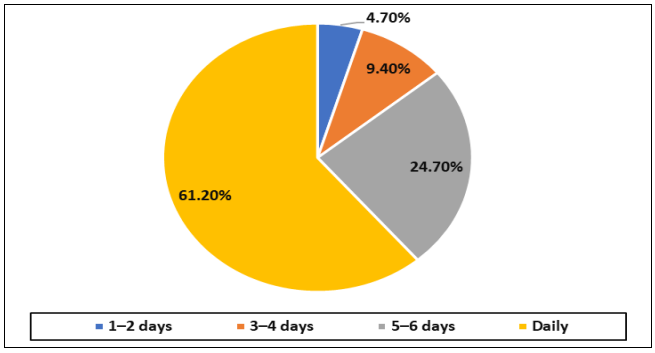


Source: Primary Data

Fig 10: Average Hours of Reliable Electricity from CBRE Systems per Day

The majority of respondents (34.1%) reported accessing between 5-7 hours of reliable electricity daily from CBRE systems, while (29.4%) enjoyed 8-10 hours, and (15.3%) benefited from over 10 hours. Conversely, (14.1%) had access for 2-4 hours, and (7.1%) reported less than 2 hours. These results demonstrate that over three-quarters (78.8%) of households enjoy at least 5 hours of power daily, suggesting that CBRE installations significantly enhance energy reliability.

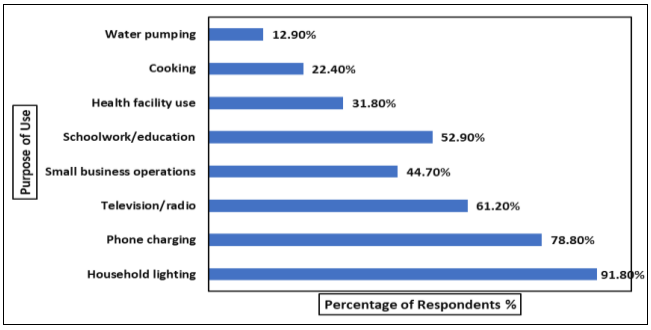
School administrators noted that solar systems "allow evening study sessions without disruptions," while some health workers emphasized that "solar lights save lives during night deliveries." These findings collectively affirm CBRE's effectiveness in improving energy reliability and service delivery in Chawama.



Source: Primary Data

Fig 11: Frequency of Weekly Usage of CBRE Systems

In Fig 11, the results indicate that the majority of respondents (61.2%) reported using their renewable energy systems daily, while (24.7%) used them 5-6 days per week. A smaller group, (9.4%), used them 3-4 days, and only (4.7%) used them 1-2 days weekly. This pattern demonstrates consistent and widespread reliance on CBRE systems for daily household activities. A local government official stated that "families depend on solar lighting every evening because ZESCO power is unreliable," while a school administrator added that "solar units support night classes even during blackouts."

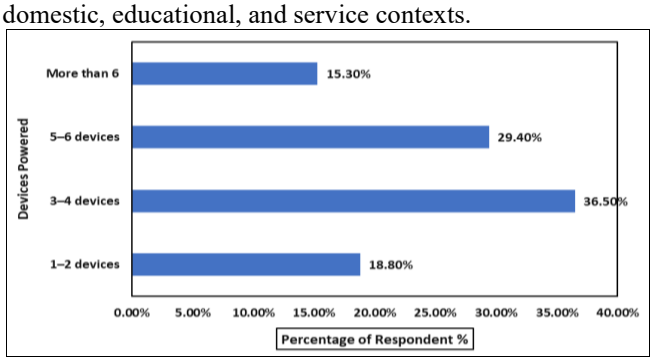


Source: Primary Data
Note: Multiple responses were allowed

Fig 12: Main Purposes of Using CBRE Systems

Findings reveal that most respondents (78; 91.8%) use CBRE systems for household lighting, followed by phone charging (67; 78.8%), television or radio use (52; 61.2%), and school-related activities (45; 52.9%). Additionally, 38 (44.7%) used them for small-scale business purposes. A school administrator explained that "solar energy has enabled pupils to extend study hours into the night," while a health worker noted that "clinic operations now continue past sunset thanks to reliable solar lighting." These results

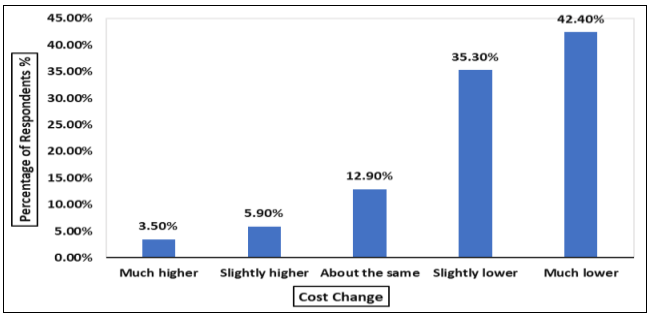
emphasize the broad functional value of CBRE systems in domestic, educational, and service contexts.



Source: Primary Data

Fig 13: Number of Devices Powered by CBRE Systems

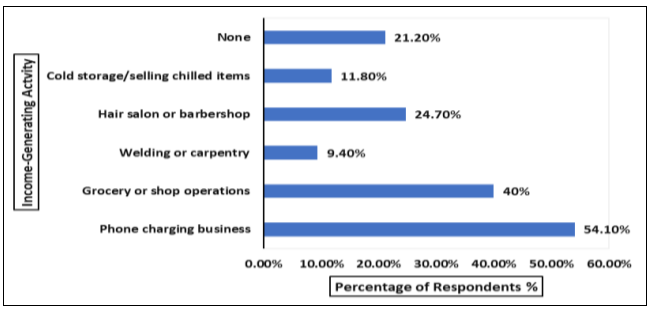
Findings in Fig 13 show that 36.5% of the respondents powered 3–4 devices, while 29.4% powered 5–6, and 15.3% powered more than 6 devices. Only 18.8% used their CBRE systems for 1–2 devices. This pattern suggests that medium-capacity systems are most common in Chawama, supporting essential household needs such as lighting, entertainment, and charging. A local official remarked that "most homes now run televisions and fridges on solar," indicating an upward shift in technological usage enabled by CBRE adoption.



Source: Primary Data

Fig 14: Comparison of Monthly Energy Costs Before and After CBRE Installation

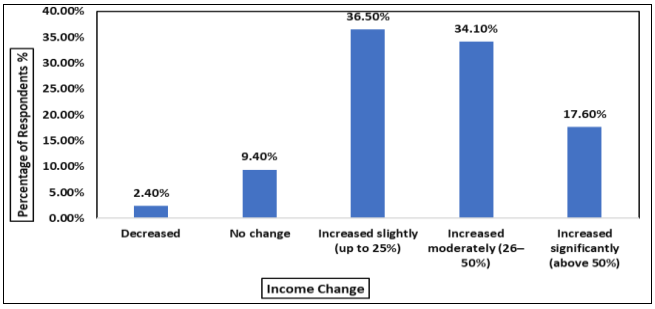
Majority of respondents (77.7%) reported reduced monthly energy costs after adopting CBRE systems, where (35.3%) slightly lower and (42.4%) much lower, while (12.9%) reported no change and only (9.4%) experienced cost increases. This clearly shows that renewable energy has significantly reduced household expenses on candles, kerosene, and electricity. A health worker noted that "solar lighting has cut fuel costs by more than half," reinforcing CBRE's affordability advantage for low-income communities.



Source: Primary Data
Note: Multiple responses were allowed

Fig 15: Income or Livelihood Activities Supported by CBRE Systems

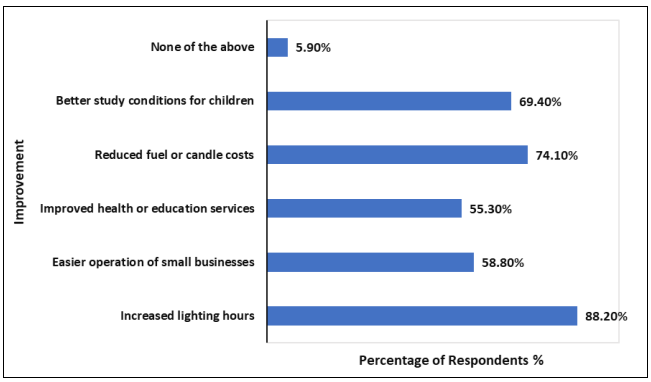
In Fig 15 more than half (46; 54.1%) of respondents reported using CBRE systems to operate phone charging businesses, followed by 34 (40.0%) who ran grocery shops and 21 (24.7%) involved in hair salons or barbershops. Only 8 (9.4%) engaged in high-load activities such as welding. A local government representative explained that "solar kiosks have helped youths earn income through phone charging and small trades," reflecting CBRE's growing contribution to local entrepreneurship and job creation.



Source: Primary Data

Fig 16: Change in Household or Business Income After Using CBRE

According to Fig 16 a significant (88.2%) of respondents reported an increase in income after adopting CBRE systems, with (36.5%) experiencing slight growth, (34.1%) moderate increases and 17.6% significant increase. (11.8%) reported no change or decline. A local government official highlighted that "solar-driven kiosks have boosted household earnings by supporting daily cash-generating activities," while a health worker added that "households now save more since they spend less on energy." These findings confirm CBRE's positive socio-economic impact in Chawama.

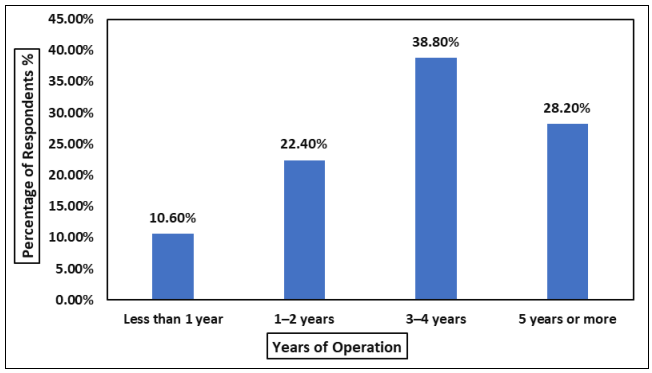


Source: Primary Data

Fig 17: Improvements Experienced Since Using CBRE Systems

The majority of respondents (75; 88.2%) reported increased lighting hours, followed by 63 (74.1%) who experienced reduced fuel or candle costs, and 59 (69.4%) noting better study conditions for children. Additionally, 47 (55.3%) cited improved health and education services. A health worker emphasized that "solar lights have made night deliveries safer," while a school administrator observed "clearer learning environments for evening classes." These findings confirm that CBRE enhances both household welfare and public service delivery.

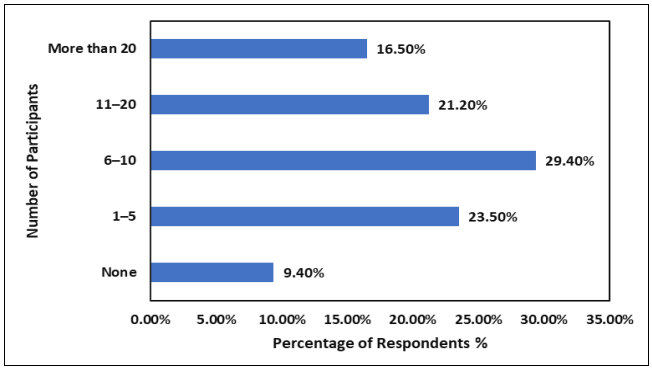
4.4 Sustainability of Community-Based Renewable Energy Solutions



Source: Primary Data

Fig 18: Duration of Continuous Operation of CBRE Systems

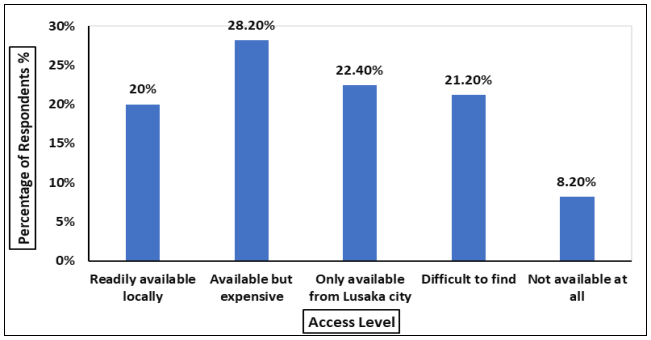
Fig 18 shows that 33 respondents (38.8%) reported systems operating continuously for 3-4 years, while 24 (28.2%) had used theirs for over five years, and 19 (22.4%) between one and two years. Only 9 (10.6%) reported systems installed within the past year. This indicates that most CBRE systems in Chawama have achieved medium- to long-term functionality. A school administrator stated that "our solar panels have worked well for more than four years," while a health worker confirmed that "older systems still power critical equipment."



Source: Primary Data

Fig 19: Community Involvement in System Management and Maintenance

About 25 respondents (29.4%) reported that 6–10 community members were actively involved in CBRE system management, while 18 (21.2%) mentioned 11-20 members and 14 (16.5%) reported over 20. However, 8 (9.4%) indicated no participation. These results suggest a fair level of community engagement in maintenance. A local government official observed that "committees are now taking ownership of solar kiosks," while a health worker added that "user groups often coordinate cleaning and minor repairs."



Source: Primary Data

Fig 20: Accessibility of Spare Parts and Technical Support

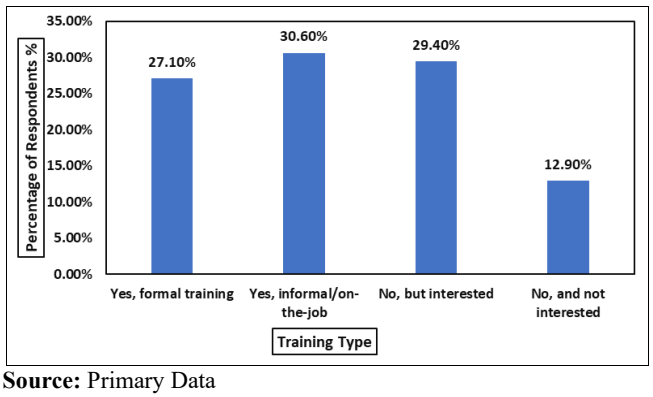
24 respondents (28.2%) found spare parts available but costly, 19 (22.4%) could only source them from Lusaka, and 18 (21.2%) reported difficulty finding them. Only 17 (20.0%) said parts were readily available locally. A local government official explained that "many suppliers are in Lusaka, increasing repair costs," while a school administrator added that "local technicians can fix minor issues but struggle with major faults." This highlights logistical and financial barriers to sustainability.

Table 3: Functionality of CBRE Systems After Donor or Government Support

System Status	Frequency	Percentage	Cumulative Percentage
Yes, fully functioning	28	32.9	32.9
Yes, but with minor issues	31	36.5	69.4
No, it stopped working	14	16.5	85.9
Not applicable/never supported	12	14.1	100
Total	**85**	**100**	

Source: Primary Data

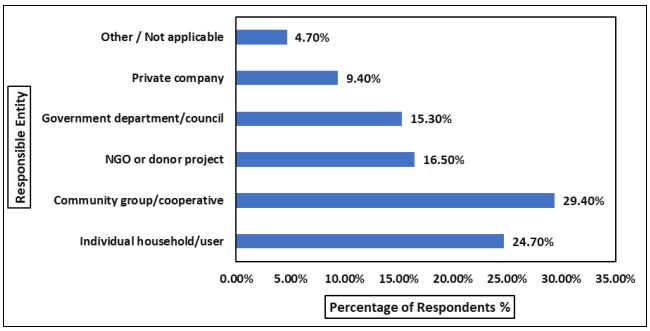
In Table 3, 31 respondents (36.5%) reported systems functioning with minor issues after donor exit, while 28 (32.9%) remained fully operational. Conversely, 14 (16.5%) noted system failure post-support. A health worker explained that "projects that trained locals kept running," while a local official added that "systems without community ownership stopped once NGOs left." These findings underscore the link between local capacity and post-donor sustainability.



Source: Primary Data

Fig 21: Training and Capacity Building in Maintenance or Management

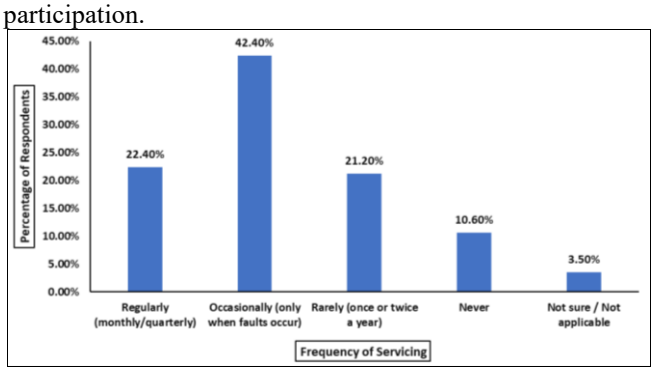
Fig 21 indicates that out of 85 respondents, 26 (30.6%) received informal maintenance training, 23 (27.1%) formal sessions, and 25 (29.4%) expressed interest in future training. However, 11 (12.9%) reported no interest. A school administrator shared that "trained caretakers handle small electrical faults effectively," while a health worker remarked that "maintenance knowledge reduces downtime." The findings indicate moderate but growing technical capacity within communities.



Source: Primary Data

Fig 22: Primary Responsibility for Maintenance

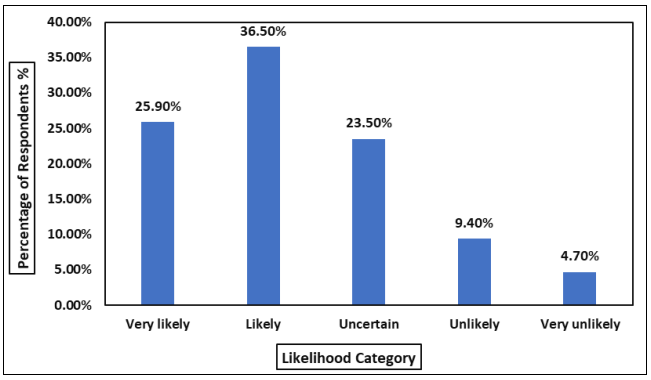
25 respondents (29.4%) identified community cooperatives as the main maintainers, followed by households (21; 24.7%) and NGOs (14; 16.5%). Local government and private entities accounted for 15.3% and 9.4% respectively. A local government representative noted that "community groups sustain most systems through joint contributions," while a school administrator mentioned that "schools depend on donor-trained caretakers." The findings reflect a hybrid maintenance model emphasizing community participation.



Source: Primary Data

Fig 23: Frequency of Maintenance or Servicing of CBRE Systems

According to Fig 23 maintenance was mostly reactive, with 36 respondents (42.4%) reporting occasional servicing, 19 (22.4%) regular schedules, and 18 (21.2%) rare maintenance. Only 9 (10.6%) never conducted servicing. A local official observed that "systems are fixed only when they break down," while a health worker noted that "regular cleaning and battery checks extend lifespan." These findings reveal a need for structured maintenance routines to ensure sustainability.



Source: Primary Data

Fig 24: Likelihood of CBRE Systems Remaining Functional in the Next Five Years

A combined 53 respondents (62.4%) believed their systems are "likely" or "very likely" to remain functional for the next five years, while 20 (23.5%) were uncertain and 12 (14.1%) doubted longevity. A school administrator stated that "solar units will last if spare parts stay affordable," whereas a local government official warned that "lack of regular servicing could shorten lifespan." These insights suggest cautious optimism toward long-term sustainability.

4.5 Discussion of Results

4.5.1 Types of Community-Based Renewable Energy Solutions

From the findings, it has been established that the community-based renewable energy landscape in Chawama is largely dominated by solar technologies, particularly solar home systems, lanterns, and kiosks. These systems have become the most practical and accessible sources of energy in the area, providing lighting, phone charging, and small-scale business power solutions. Their widespread use represents a strong community-driven adaptation to unreliable grid electricity and high energy costs. The study further revealed that most of these systems were acquired either through personal investment or through the support of non-governmental organizations, with minimal government involvement. This highlights the proactive role of local communities and civil society in promoting renewable energy access. Additionally, the study noted increasing gender inclusivity, as women were actively engaged in the management and operation of these systems, particularly in female-headed households. Overall, the dominance of solar technologies demonstrates both the practicality and social acceptance of decentralized renewable energy in meeting everyday household and economic needs.

4.5.2 Effectiveness of Community-Based Renewable Energy Solutions

The study revealed that community-based renewable energy systems have significantly improved energy reliability and contributed to socio-economic advancement in Chawama. Many households now enjoy steady access to electricity for lighting, communication, education, and small-scale

business operations. These systems have also reduced dependence on costly and unreliable grid power while lowering household energy expenses. Through enhanced access to reliable energy, families have experienced improved living conditions, better study environments for children, and expanded opportunities for income generation, especially through enterprises such as phone charging kiosks, retail shops, and salons. The findings further show that renewable energy adoption has strengthened local resilience and reduced energy poverty by enabling households to redirect savings toward other essential needs. Therefore, CBRE systems have proven effective not only in supplying power but also in enhancing livelihoods, supporting education, and improving the overall quality of life for Chawama residents.

4.5.3 Sustainability of Community-Based Renewable Energy Solutions

The findings established that while community-based renewable energy systems in Chawama have shown strong potential for long-term functionality, sustainability remains uneven across projects. Systems managed through community cooperatives and women-led groups demonstrated higher durability due to consistent maintenance practices, access to spare parts, and locally available technical training. In contrast, systems dependent solely on donor support faced operational challenges after funding ended. The study further found that ongoing maintenance and the presence of trained caretakers were vital for system endurance, while high costs of spare parts and reliance on urban centers for replacements hindered sustainability. Institutional sustainability was strongest where communities actively participated in governance and reinvested in system upkeep. Overall, the findings indicate that long-term success of renewable energy initiatives in Chawama depends on participatory governance, capacity building, and local ownership. This community-centered approach enhances accountability, promotes equitable participation, and ensures that renewable energy systems continue to deliver social and economic benefits over time.

5. Conclusion

It is evident that community-based renewable energy (CBRE) solutions are a vital source of sustainable development and an important driver of clean energy access in peri-urban areas. CBRE initiatives have demonstrated the potential to address persistent electricity shortages and improve livelihoods through affordable, reliable, and environmentally friendly energy alternatives. However, the development and management of such systems in Zambia still face challenges such as limited technical capacity, weak institutional support, and inadequate government participation, which hinder their long-term sustainability and expansion. However, the objective of this study was to examine the effectiveness of community-based renewable energy solutions in addressing clean energy gaps in Chawama Constituency, Lusaka. Thus, the study concludes that CBRE systems have significantly enhanced energy access and reliability while stimulating household welfare and small-scale business development. The study further established that solar technologies, especially home systems and kiosks, have become the most effective means of bridging local energy gaps. Moreover, the research revealed that community-driven and NGO-led initiatives have been more impactful than government interventions, highlighting the importance of participatory governance and local empowerment. Lastly, this study was confined to Chawama Constituency. For further research, it would be valuable to conduct similar studies in other districts across Zambia to assess whether similar outcomes regarding energy access, justice, and sustainability would be achieved.

5.1 Recommendations

The study recommends that community governance and institutional integration be strengthened by formally involving Ward Development Committees and cooperatives in Lusaka City Council's energy planning. This will promote accountability, continuity, and reduce project abandonment once donor support ends. Additionally, technical training and maintenance capacity should be enhanced through regular community-based programs supported by partnerships with technical colleges and the Rural Electrification Authority to ensure affordable repair services.

Furthermore, establishing sustainable financing mechanisms such as revolving maintenance funds and cooperative microfinance schemes will improve financial independence and long-term system upkeep. Gender and youth inclusion should also be prioritized in leadership and management roles to ensure equitable participation and enhance accountability. Lastly, embedding CBRE initiatives into local development plans and linking them to income-generating activities such as agro-processing and small enterprises will improve productivity, livelihoods, and community reinvestment capacity.

6. Acknowledgement

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Lastly, I thank my family and friends for their patience, motivation, and unwavering belief in me. Your support has meant everything.

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